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Distribution of the tick *Dermacentor reticulatus* in the United Kingdom

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Abstract

The recent implication of *Dermacentor reticulatus* (Acari: Ixodidae) in the transmission of canine babesiosis in the United Kingdom (UK) has highlighted the lack of published accurate data on their distribution in the UK. This paper aims to collate and appraise historical data of *D. reticulatus*, supplements it with more recent surveillance data and reports on field sampling conducted 2009-2016. This updated data provides a better understanding of the current distribution of this tick in the UK to better inform disease risk assessments. There appear to be four known regions of the UK where *D. reticulatus* currently occurs: West Wales, North and South Devon and Essex. The majority of foci are in coastal sand dune and maritime grasslands, including grazing marsh. However more recently the tick has been detected in urban greenspace in Essex. The emergence of this tick as a vector of babesiosis in the UK, and its recent apparent spread in Essex into urban greenspace highlights the need for continued surveillance and for further research into its vector status for human and veterinary pathogens.

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Introduction

In Europe, *Dermacentor reticulatus* is an important vector of *Babesia canis* and *Babesia caballi,* causing babesiosis in dogs and horses, respectively, as well as *Rickettsia slovaca* and *R. raoultii,* which are responsible for a syndrome in humans characterised by scalp eschars and neck lymphadenopathy (SENLAT) previously known as tick-borne lymphadenopathy (TIBOLA), or *Dermacentor*-borne necrosis erythema and lymphadenopathy (DEBONEL) (Rubel *et al*., 2016; Földvári *et al*., 2016). The species has also been associated with transmission of tick-borne encephalitis virus to humans (Karbowiak & Biernat, 2016). *Dermacentor reticulatus*, known as the Marsh, Ornate Cow or Meadow tick (Figure 1), is endemic in Europe with a distribution stretching from Portugal in the west to Ukraine and Turkey in the east. The southernmost limits of its range occur in northern Portugal and Spain, northern Italy, Bulgaria and Turkey, whereas there are no records further north than Wales and Latvia (Rubel *et al*., 2016; ECDC VectorNet, 2016; Földvári *et a*l., 2016; Olivieri *et al*., 2016). It has a patchy distribution throughout its range, showing a general localisation in moist habitats such as alluvial forests, swamps, lake shores and riverbanks, although it is also known to inhabit drier areas including woodland edge, heathland, grassland, sand dunes and even suburban forest (Tharme 1993; Rubel *et al*., 2016; Földvári *et al*., 2016).

Recent reports of canine babesiosis caused by *B. canis* in Essex (Hansford *et al*., 2016; Phipps *et al*., 2016; Swainsbury *et al*., 2016) have raised interest in the distribution of *D. reticulatus* in the United Kingdom (UK). This follows from previous UK studies that have highlighted the presence of tick-borne rickettsiae in populations of *D. reticulatus* (Hubbard *et al*., 1998; Tijsse-Klasen *et al*., 2011, 2013; Abdullah *et al*., 2016). There have been limited reports on the distribution of *D. reticulatus* in the UK (Jameson & Medlock, 2011; Medlock *et al*., 2011) and very little research conducted to understand its biology, ecology and phenology. The exception is the work of Tharme (1993) who focussed on populations in Wales. Knowledge of its distribution, basic ecology and biology is important if attempts are to be made to minimise tick-bite risk and manage habitats where this species is present and causing a localised disease risk, as has been reported recently for the first time in the UK with regards to *B. canis* transmission (Swainsbury *et al*., 2016).

Dermacentor reticulatus is the only member of the *Dermacentor* genus of Ixodid tick that is established in the UK; an additional species *D. marginatus* occurs in Europe, and has only been reported as imported in the UK (Pietzsch *et al*., 2015). Adults of this genus are tolerant of extreme environments, able to survive under water for long periods of time in flooded river valleys elsewhere in its European range (Foldvari *et al*., 2016). It is also known to be active during the winter (Tharme, 1993) and during periods when other tick species, such as *Ixodes ricinus* are not active, with evidence that it can tolerate long periods below 0^{o}C in the laboratory (Zahler, 1994). Unlike other tick species, the adults may live for long periods (up to four years) without a blood meal (Foldvari *et al*., 2016), with the female tick laying more than 7000 eggs (Simo *et al*., 2004), which is significantly higher than *I. ricinus*.

Our knowledge of the immature stages of this tick however are limited, with both the larva and nymph considered to be mainly nidicolous, unlike the adults which are exophilic, questing in the environment,

rather than remaining in the host's nest (Arthur, 1960; Pfaffle *et al*., 2015; Foldvari *et al*., 2016). This makes detection of the immature stages by flagging extremely rare and generally it is only the adult stages that are collected from vegetation (Tharme, 1993). The immatures can be found engorged on trapped small mammals (e.g. rabbits, hares, shrew, voles and moles [hosts reviewed in Foldvari *et al*., 2016]). Larvae are usually detected during May-July (Arthur, 1960; Pfaffle *et al.*, 2015). Having fed, the resulting nymphs from the moult are active within a month. The nymph can be collected from animals (often including shrews and field voles) during July-August of the same year. Adult stages are reported to be mainly active in Europe during March and April with a second peak in the autumn (September-October) (Nosek, 1972; Foldvari *et al*., 2016). Although the adults can be found questing during mild winters, they usually show winter diapause, and although the whole life cycle can be completed within one year, unfed adults can overwinter to quest in the spring (Nosek, 1972). As with *I. ricinus* they adopt an ambush strategy, acquiring a host by questing on vegetation; although they are attracted by host odours, and can appear more commonly on the edge of paths where they are more likely to encounter a host (Tharme, 1993).

Although populations of this tick have been reported in the UK for more than one hundred years (Martyn, 1988; Hubbard *et al*., 1998), there is little information on whether these historical populations still exist, or indeed whether they actually constituted an established population. A key element of disease risk assessment is an understanding of the distribution, abundance and suitable habitats of the vector, as well as their seasonal activity. Unlike the more commonly encountered *I. ricinus* the distribution and habitat requirements of *D. reticulatus* are poorly studied in the UK (Medlock & Jameson, 2010). This paper aims to firstly summarise the historical and current distribution data on *D. reticulatus,* and secondly to investigate historical foci and possible current foci based upon eight years of field surveys, to provide greater clarity on the currently known distribution and habitats of *D. reticulatus* in the UK. This work aims to build on previous reports (Evans, 1951; Jameson & Medlock, 2011; Smith *et al*., 2011), to permit a more comprehensive assessment of their potential role as disease vectors.

Methods

This paper collates passive surveillance data, both historical and more recent data, as well as report on targeted field surveillance. It summarises the historical and current distribution of *D. reticulatus* in the UK by firstly collating and appraising all historical records held by the Biological Records Centre (BRC) and supplementing them with recent records.

Secondly, the paper presents the results of targeted field surveys during 2009-2016 of sites historically known to support this tick species, and sites where potential new foci of these ticks have recently or previously been reported. Sites were selected in Wales, Devon and Essex based upon a) where ticks had previously been reported, b) neighbouring sites that offered similar habitat [informed by the field surveys] and c) sites in the vicinity of recent submissions to the schemes. The aim being to catalogue known foci of *D. reticulatus* and make some qualitative assessment of their habitat preference, host associations and tick density. It should be noted that PHE have run a tick surveillance scheme (TSS) from 2005, so this data was used to carefully select where *D. reticulatus* might occur. The majority of tick submissions to the TSS are *Ixodes* sp. so the lack of submissions of *D. reticulatus* across most of the country is used to inform areas of possible absence; particularly as this tick species is easily acquired by dogs, and as there are many submissions of ticks from dogs.

Field studies using standard tick dragging methods (1m x 1m brushed cotton blankets) for *D. reticulatus* were carried out in coastal habitats in West Wales (between Harlech and Aberaeron) every March during 2010-2012; in North Devon (Woolacombe-Braunton) during May 2010, April 2011, March 2012 and March 2015; South Devon (Hope Cove-Start Point) during March 2011, in Essex (Southend region) during March 2009 and March-April 2010, and around Harlow and Tollesbury in March/April and October 2016. Exact locations of survey sites and times of survey are detailed in Table 1.

Where possible all dragging was conducted at random and continued until at least one hour of surveying had been completed at each site by at least two field surveyors. Surveying was conducted after 1100 and during fine, dry weather. Number of ticks collected during this time frame is reported in Table 1, however as the aim of this study is to catalogue known foci, and each visit constitutes a snapshot survey, no attempt has been made to compare tick densities between sites. However reporting actual numbers of ticks collected provides some qualitative information on the densities of ticks that may be present at each site.

Field studies were conducted initially to investigate whether the possible historical foci of established *D. reticulatus* still exist, and also to follow up any additional reports of this tick submitted to the TSS during this period. Established populations are considered to exist where more than one adult ticks was found or at least one tick was found on more than one occasion. As immature *D. reticulatus* ticks are not collected by flagging, the presence of questing adult ticks is considered sufficient to determine local populations.

Results

Historical records

Records of all tick species held by the BRC prior to 2005 were obtained and digitised. Historical records of *D. reticulatus* recorded prior to 2005 include 90 records with data submitted between 1900 and 1988. The majority of records have been reported since 1950 (64/90; 71%). Half of all the records of *D. reticulatus* are from Wales (46/90), with 27 records from Devon.

The Welsh records indicate the historical occurrence of possibly five main foci, all located on the Merioneth and Ceredigion coast. These include from north to south: Morfa Harlech (10 records from sheep, dogs, cats and on clothing; 1967-1988), Morfa Dyffryn (17 records mostly from dogs and humans; 1966-1971), Broadwater/Morfa Gwyllt, near Tywyn (7 records from dogs and humans; 1968-1972), Cors Fochno/Borth Bog [inc. Tre'r-ddol] (3 records on cattle and sheep; 1951-1988) and Aberystwyth [inc. Pen Dinas, and Llanfihangel-y-Creuddyn] (6 records on dogs and sheep; 1913-1956). The majority of these reports are from the 1960s-1980s, with almost all records reported between September and March (all adult stages, no immature stages). A further three records are reported from other parts of Wales with little supporting information, with only St. David's and Tal-y-llyn listed as specific locations (1957-1988).

In Devon, the historical data suggest that there may have been six historical foci of *D. reticulatus* across the county [all records are adult *D. reticulatus* unless otherwise stated], three in the north: at Woolacombe (2 records from dogs; 1972), Braunton Burrows (3 records, one from a dog, one from vegetation and one larva on *Microtus agrestis* [field vole]; 1972-1973) and near Bideford (two records on dogs, 1938); with three sites in south Devon near Exeter (2 records in vegetation and on humans, 1956), Newton Abbot (2 records from a lily field in 1916 and 1988) and the South Hams region of Revelstoke [inc. Stoke House], Newton Ferrers (4 records from Sheep in 1900s and 1950s) and Yealmpton (1915; no host data). There are six records of adult ticks on humans or their clothing from Paignton (1938-1949), two nymphs on a skylark (*Anthus pratensis*) on Lundy Island (1953) and three other non-specific sites reporting adult *D. reticulatus* in vegetation on the River Dart (1916), a site near Totnes (1972), and two records from Plymouth. There is not enough evidence to determine whether any of the latter records constitute local populations.

The remaining 16 historical records [all adult ticks] not from Wales or Devon are more dispersed, with three records from 1944-1951 in Polbathic (Cornwall) and from 1944 and 1964 in Forrabury, Boscastle (Cornwall), with single reports from Camborne (1988) and Cornwall (1972). Two reports are from cattle (Weston-Super-Mare, 1969) and sheep (1937) in Somerset; a single report from Corfe Mullen (Dorset) on cattle (1968), and single ticks are from a dog in Surrey (Reigate, 1976), on a human in Lancashire (Blackburn, 1977), and in a house in Gloucestershire (Coleford, 1988). Three additional reports are from other locations with insufficient information to locate them with reportable precision. None of these seem to constitute local populations as there have been no subsequent records from these localities.

According to these historical records, *D. reticulatus* has been found in the UK in every month of the year, with the majority of records of adults reported during September to June with a particular peak in March and April, suggesting that this is their main period of activity (Figure 2). The records of occurrence of immature stages is rare and little is known about the hosts of these stages in the UK (Tharme, 1993).

Recent records from PHE Tick Surveillance Scheme (TSS)

Since the establishment of the TSS in 2005, run by PHE's Medical Entomology group, there have been an additional 27 separate records of *D. reticulatus* that have not been associated with overseas travel. Seven records have been submitted during 2016, the highest number of records received in a single year to date. Sixteen records have been from dogs, eight from humans (with three records reporting the tick actually biting), two from horses [Potton Island], and one from sheep [near Aberystwyth]. All submissions were of adult *D. reticulatus* (41♂, 61♀) submitted between mid-February and early June (Figure 2), with the majority of records received during March and April. Human records have been from Devon (Bideford, Northam, Plymouth, East Prawle) and Essex (Southend, Coggeshall, Old Hall Marshes). One additional record came through a hospital in Walsall but the location of tick exposure is unknown. Records from dogs have been submitted from Devon (six from Northam Burrows, also Kingsbridge), Essex (Old Hall Marshes, two from Tollesbury Wick, one from Fryerning) and East London (one from Hackney Marshes). All but two of the records from dogs and humans from Essex were reported in 2016. It is not clear that all these reports constitute local populations, as many reports were associated with visits to other localities in Essex, including Old Hall Marshes and Tollesbury Wick.

Recent records from Big Tick Project

A national survey in the UK, in which more than 1000 veterinary practices inspected 12,096 dogs and collected 6555 ticks between March and July 2015, reported only eight records of *D. reticulatus* in dogs that had been resident in the UK in the period prior to the survey (Abdullah *et al*., 2016). These included seven from Wales (or associated with travel to Wales) and one from England. Three of the Welsh records were from veterinarians from Tywyn (Gwynedd), and one each from near Aberdyfi (Gwynedd) and Newtown (Powys). The one English record was from near Bude (Cornwall).

Results of field surveys 2009-2016

D. reticulatus in Wales

Initial field studies in Wales during March 2010 focussed on historical locations on the west coast in Gwynedd, near Harlech. Adult *D. reticulatus* were found questing in sand dune habitat at Morfa Harlech (90♂, 171♀), and Morfa Dyffryn (12♂, 11♀) with >30% of all tick transects positive for ticks. *Dermacentor reticulatus* was also present in sand dune habitat at Shell Island (14♂, 23♀), although positive sites were restricted to the perimeter of the camping areas, where there was evidence of dog activity.

In March 2011 adult *D. reticulatus* were collected at Aberdyfi (Gwynedd) dunes (1♂, 6♀), however no ticks were found at other sand dune systems or sites historically reporting *D. reticulatus* at Morfa Gwyllt, Ynys Las or Cors Fochno (all Ceredigion). In March 2012, Ynys Las was re-visited but no ticks were

detected. However questing adult *D. reticulatus* were found at sand dunes at Morfa Gwyllt (2♂, 17♀), and at a coastal headland site at Craig yr Wylfa, Upper Borth (7♂, 12♀); the first Welsh *D. reticulatus* found questing in habitat other than sand dune. Additional surveys in suitable habitat along the Ceredigion coast at Pen Dinas (near Aberystwyth), and in coastal grassland at Penglog (near Llanrhynstud) and Clogfryn (near Aberaeron) were conducted, however no *D. reticulatus* were found. All locations are detailed in Table 1, and shown in Figure 3

The habitats where *D. reticulatus* were found in Wales were mainly in dynamic dune habitats dominated by *Ammophila arenaria* (marram grass), *Salix* sp. (willow) and *Rosa pimpinellifolia* (burnet rose), except in one location where they occurred in cliff top habitat in both maritime grasses and *Holcus lanatus* (Yorkshire fog), and neutral grassland with patches of scrub and bracken. Hence field surveys between 2010 and 2012 confirmed six main foci for questing adult *D. reticulatus* on the west Welsh coast (Morfa Harlech, Shell Island, Morfa Dyffryn, Morfa Gwyllt, Aberdyfi dunes [all Gwynedd] and Upper Borth [Ceredigion]).

D. reticulatus in Devon

Initial surveys in May 2010 in North Devon found only one female *D. reticulatus* collected at Braunton Burrows, and no ticks at an historical site at Woolacombe Down. The sand dune habitats in North Devon are similar in structure and vegetation to the dune systems described above in Wales. At Braunton no ticks were found in April 2011 and only one female *D. reticulatus* was collected in 2012. More recently (2014-2015) however, in North Devon, numerous *D. reticulatus* submissions to the TSS have been associated with Northam Burrows (near Westward Ho!), and a field visit in March 2015 confirmed a questing population (14♂, 13♀); the only known significant focus so far found in North Devon.

In South Devon, large numbers of questing *D. reticulatus* were found in March 2011 at Bolt Tail (near Hope Cove; 34♂, 79♀) associated with grazing sheep pasture; low numbers were found at The Warren (near Soar; 3♀) and Prawle Point (1♀). Other potential sites at Bolberry Down or Start Point detected no ticks. Although *D. reticulatus* generally appears to occur at low numbers at sites on the south Devon coast, a significant population of questing ticks appears, based upon these surveys, to be present at Bolt Tail. All locations are detailed in Table 1, and shown in Figure 3. Habitats here were south-west facing cliff top habitat dominated by grasses *Holcus lanatus* and *Festuca rubra* (red fescue), and plantains *Plantago maritima* (sea plantain) and *Plantago coronopus* (buckshorn plantain). There were also patches of *Erica cinerea* (bell heather) and *Ulex europaeus* (gorse).

D. reticulatus in Essex

Initial reports of *D. reticulatus* on dogs on Potton Island in 2008 were investigated in March 2009 and March 2010. Initially in 2009 there was no access to the island, however questing adult ticks were found in publicly accessible, semi-improved, un-grazed grassland with patches of scrub near Great Wakering in 2009 (7♂, 18♀), and this population was still extant in 2010 (2♂, 3♀). Access to horse grazing rough pasture on Potton Island in 2010 confirmed local questing *D. reticulatus* (4♂, 11♀). Despite further surveys in 2009 at Fleet Head, Barling, Mucking and Shopland (all near Southend) and in 2010 at

Shopland, Galleywood Common (near Galleywood), Chignall St James (near Chelmsford), Lawford Lane (near Writtle), Paglesham, Great Stanbridge, Wallasea Island and Canewdon (all near Rochford), no further populations were found. Therefore as of 2010, there were only two known sites with questing adult *D. reticulatus* in Essex (Potton Island and Great Wakering) although the occurrence of other foci was anticipated (Jameson and Medlock, 2009).

More recently, following reports of canine babesiosis in Harlow, field surveys were conducted during March 2016 in an urban wooded grassland in the town where a small focus of questing adult ticks were found (9♂, 8♀). The habitat here was typical of urban greenspace, with areas of improved grassland, scrub, and stands of woodland. Although not recently grazed, horses are grazed locally, and it is a regular dog walking area. Following a TSS report of *D. reticulatus* from the Hackney area, sampling in April 2016 at Hackney Marshes and Walthamstow Marshes found no evidence of ticks. Since then field sampling has confirmed the presence of questing *D. reticulatus* at Old Hall Marshes, Tollesbury, Essex (11♂, 29♀). Additional reports in the vicinity of Tollesbury Wick require further field investigation to confirm tick presence and follow-up surveys during 2017 are needed to ascertain population establishment and additional sites in Essex. All locations are detailed in Table 1, and shown in Figure 3

Discussion

An appraisal of historical records of *D. reticulatus*, coupled with more recent records from two surveillance programmes, as well as field surveys during 2009-2016 confirm the presence of four main areas for *D. reticulatus* in England and Wales: West Wales, North Devon, South Devon and Essex (Figure 3). Surveillance data and targeted field studies confirm that there are populations of questing *D. reticulatus* in a number of dune habitats (Figure 4) in west Wales between Afon Glaslyn and Afon Dovey, being particularly common at Morfa Harlech, and also in coastal headland habitat near Borth. The latter corresponds with published records of *D. reticulatus* found feeding on cattle at two farms near Borth Bog (Evans, 1951). Interestingly at Shell Island adult ticks were only found in close proximity to the camping ground, suggesting that dogs are perhaps important hosts in feeding *D. reticulatus* populations at this site. At Morfa Harlech and Morfa Dyffryn, cattle are likely to be important hosts for adult stages of *D. reticulatus* (Evans, 1951), but the possible association with rabbits (or their burrows) suggest that this host species may play an important role in feeding the immature stages of *D. reticulatus*. However no mammal trapping was conducted to confirm the presence of ticks on rabbits or other small mammals (e.g. Field vole *Microitus agrestis*), and this could be studied further. At both Morfa Harlech and Aberdovey, the ticks were found questing along the margins of fairways on links golf courses where dogs visit regularly, with few grazing livestock. These field surveys from Wales highlight the association with sand dune habitat in the UK, which is in contrast to most locations in Europe where *D. reticulatus* appears to be more associated with moist environments and river valleys. The occurrence of ticks on the edge of trackways, camping grounds and golf fairways supports previous reports by Tharme (1993) that these ticks appear to quest on the edge of habitat where hosts might be passing, particularly dogs that are walked regularly along the same route.

The spatial distribution of *D. reticulatus* historically, with the exception of the Essex population, appears to have been restricted to coastal habitats (principally dune systems, but also coastal grassland) in West Wales and North and South Devon. In Devon, the ticks occur in a number of sites between Bolt Tail and East Prawle on the south Devon coast, and at Northam Burrows and Braunton Burrows in North Devon. However, the only significant populations in Devon, based upon the field surveys, were at Bolt Tail (South Devon) and Northam Burrows (North Devon). Ticks were found on horses at Northam Burrows, and given that this site is common grazing, it may act as a source for wider dissemination of this tick species within the vicinity.

The appearance of these ticks in Essex, possibly linked to a movement of animals, highlights the ease with which *D. reticulatus* may be transported on livestock (and possibly dogs) and subsequently establish in new areas. The potential for further spread in Essex was therefore anticipated (Jameson & Medlock, 2009), and recent evidence suggests that the Essex population may have spread. In addition to the sites around Potton Island, there have recently been records from Harlow and near Tollesbury, and it is likely that other sites will be detected in the coming years. Although dogs are commonly bitten by these ticks, other animals found in these *D. reticulatus* foci in the UK, such as cattle, sheep and horses are also reportedly infested, as has been recorded elsewhere (Mierzejewska *et al.*, 2015). If these animals are moved from one site to another for grazing, as frequently occurs in nature reserves,

then ticks may continue to be disseminated. Treatment of such grazing animals with acaricide might assist with minimising local tick populations and preventing their spread to new sites. However, very little information exists on the environmental control of *D. reticulatus* within the UK, so sharing distribution data in a timely manner and raising awareness of the potential public and animal health threats posed in areas where localised populations exist, must be part of response activities to what appears to be a changing eco-epidemiological picture for *D. reticulatus* in the UK.

Ideally the detection of immature stages either by flagging or on hosts would confirm that all stages are feeding and surviving locally. However immatures are not readily acquired by flagging and the logistics of mammal trapping was beyond the scope of this surveillance, but could form part of further research into this tick species in the UK. It is likely that there are also other sites across the UK which so far our surveillance (either passive or active) has yet to identify. Indeed there are several other sand dune systems on the Welsh coast in the counties of Pembrokeshire, Swansea (Gower) and Bridgend and these require subsequent surveys. However if populations do occur then issues with ticks at any of these sites have not been detected through existing surveillance systems. Movement of animals, both livestock and dogs, are likely to play a significant role in moving ticks from one habitat to another. Livestock are clearly an important host, with populations in West Wales, Devon and Essex notably associated with cattle, sheep and horses. Where *D. reticulatus* occur within a habitat, they can be very common, particularly during March and April.

It is noteworthy that many of the sites where *D. reticulatus* has historically, and also currently, been detected in the UK are historical rabbit warrens. Given its limited range, could this tick have been imported into the UK historically along with rabbits? Further work on the molecular variability of populations may be able to shed some light on this. What is apparent however is that in Essex, there seems to be a shift to different habitats, more associated with coastal marshes, and now also urban parkland. There are large areas of coastal Essex and Kent with grazed coastal marshes, and the possibility for movement of this tick on grazing animals within the region could easily facilitate dissemination. The use of flocks and herds of grazing animals across a number of coastal nature reserves might also facilitate this expansion. Furthermore, the population in an urban park in Harlow highlights the possibility of new urban habitats (possibly grazed by horses and livestock) being exploited. In such areas with higher human presence and pet ownership, and given the recent outbreak of canine babesiosis, *D. reticulatus* should be considered as an important tick vector in the UK.

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Table 1 – Field collections of *Dermacentor reticulatus* in England and Wales during the period 2009-2016. The numbers of ticks reported at each site relate to numbers of *D. reticulatus* collected during each visit.

Location	Region	Habitat	Lat Long	Dates	*D. reticulatus*
Morfa Harlech	Harlech, Gwynedd	Sand dune	52.9N, 4.1W	22nd-25th March 2010	90♂, 171♀
Mochras (Shell Island)	Llanbedr, Gwynedd	Sand dune	52.8N, 4.1W	22nd-25th March 2010	14♂, 23♀
Morfa Dyffryn	Dyffryn Ardudwy, Gwynedd	Sand dune	52.8N, 4.1W	22nd-25th March 2010	12♂, 11♀
Morfa Gwyllt (Broad Water)	Tywyn, Gwynedd	Sand dune & coastal grassland	52.6N, 4.1W	9-10th March 2011 March 2012	0 2♂, 17♀
Aberdyfi dunes	Aberdovey, Gwynedd	Sand dune	52.5N, 4.1W	9-10th March 2011	1♂, 6♀
Twyni Bach (Ynys las)	Borth, Ceredigion	Sand dune	52.5N, 4.0W	9-10th March 2011 26th March 2012	0 0
Cors Fochno (Borth Bog)	Borth, Ceredigion	Lowland bog	52.5N, 4.0W	9-10th March 2011	0
Upper Borth	Borth, Ceredigion	Maritime grassland	52.5N, 4.1W	26th March 2012	7♂, 12♀
Pendinas	Aberystwyth, Ceredigion	Acid grassland	52.4N, 4.1W	27th March 2012	0
Pen Glog	Llanddeiniol, Ceredigion	Maritime grassland	52.3N, 4.1W	27th March 2012	0
Clogfryn	Aberaeron, Ceredigion	Maritime grassland	52.2N, 4.3W	27th March 2012	0
Woolacombe Down	Woolacombe, Devon	Sand dune	51.1N, 4.2W	4-5th May 2010	0
Braunton Burrows	Saunton, Devon	Sand dune	51.1N, 4.2W	4-5th May 2010 8th April 2011 March 2012	1♀ 0 1♀
Bolt Tail	Hope Cove, Devon	Maritime grassland	50.2N, 3.9W	22-23rd March 2011	34♂, 79♀
Bolberry Down	Bolberry, Devon	Maritime grassland	50.2N, 3.8W	22-23rd March 2011	0
The Warren	Soar, Devon	Maritime grassland	50.2N, 3.8W	22-23rd March 2011	3♀
Prawle Point	East Prawle	Maritime grassland	50.2N, 3.7W	22-23rd March 2011	1♀
Start Point	Hallsand, Devon	Maritime grassland	50.2N, 3.6W	22-23rd March 2011	0
Great Wakering	Southend, Essex	Community grassland	51.5N, 0.8E	16th March 2009 29th March 2010	7♂, 18♀ 2♂, 3♀
Fleet Head	Southend, Essex	Grazed grassland	51.6N, 0.8E	16th March 2009	0
Barling	Southend, Essex	Grazed grassland	51.6N, 0.8E	16th March 2009	0
Mucking	Southend, Essex	Grazed grassland	51.6N, 0.8E	16th March 2009	0
Shopland	Southend, Essex	Grazed grassland	51.5N, 0.7E	16th March 2009 29th March 2010	0 0
Potton Island	Southend, Essex	Grazed grassland	51.6N, 0.8E	29th March 2010	4♂, 11♀
Galleywood Common	Galleywood, Essex	Grazed grassland	51.7N, 0.5E	Early April 2010	0
Chignall St James	Chelmsford, Essex	Grazed grassland	51.8N, 0.4E	Early April 2010	0
Lawford Lane	Writtle, Essex	Grazed grassland	51.7N, 0.4E	Early April 2010	0
Paglesham	Rochford, Essex	Grazed grassland	51.6N, 0.8E	Early April 2010	0

Great Stanbridge	Rochford, Essex	Grazed grassland	51.6N, 0.7E	Early April 2010	0
Wallasea Island	Rochford, Essex	Grazed grassland	51.6N, 0.8E	Early April 2010	0
Canewdon	Rochford, Essex	Grazed grassland	51.6N, 0.7E	Early April 2010	0
Northam Burrows	Westward Ho!, Devon	Sand dune	51.0N, 4.2W	12th March 2015	14♂, 13♀
Central Harlow	Harlow, Essex	Urban grazed parkland	51.7N, 0.1E	11th March 2016	9♂, 8♀
				13th October 2016	0
Old Hall Marshes	Tollesbury, Essex	Grazed grassland	51.8N, 0.8E	31st March 2016	11♂, 29♀
				13th October 2016	0
Hackney Marshes	Hackney, London	Urban parkland	51.3N, 0.0W	31st March 2016	0
				25th April 2016	0
Walthamstow Marshes	Walthamstow, London	Urban parkland	51.3N, 0.0W	25th April 2016	0

Figure 1. Female and Male *Dermacentor reticulatus*

Figure 2. Seasonality of historical (black) and recent (grey) records of *Dermacentor reticulatus* in the UK during the period 1900-2016.

Note no date was given for 22 historical records.

Figure 3. Current known distribution of *Dermacentor reticulatus* based upon a) submissions to the PHE Tick Surveillance Scheme, b) the Big Tick Project, and c) field collections conducted during 2009-2016.

Figure 4. Questing *Dermacentor reticulatus* in sand dune habitat

Fig 1

Fig 2

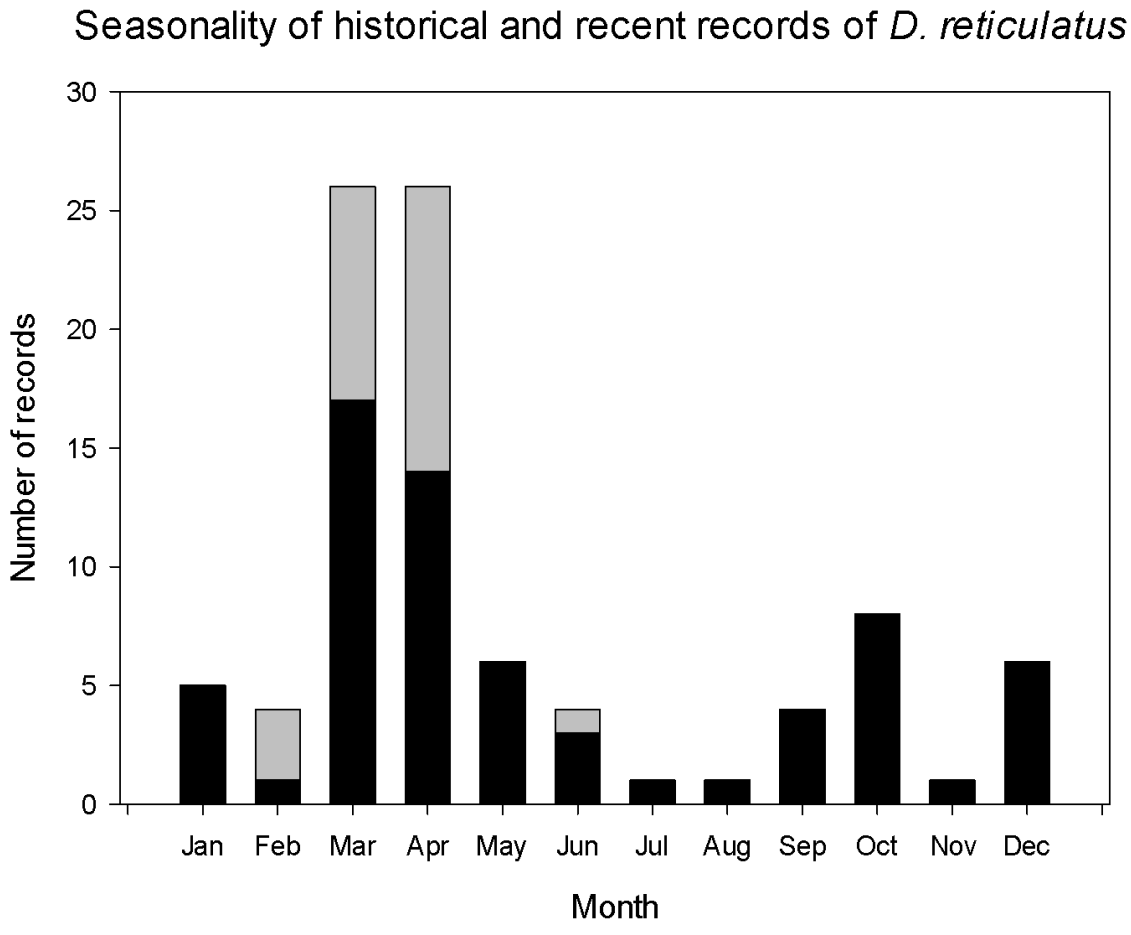

Fig 3

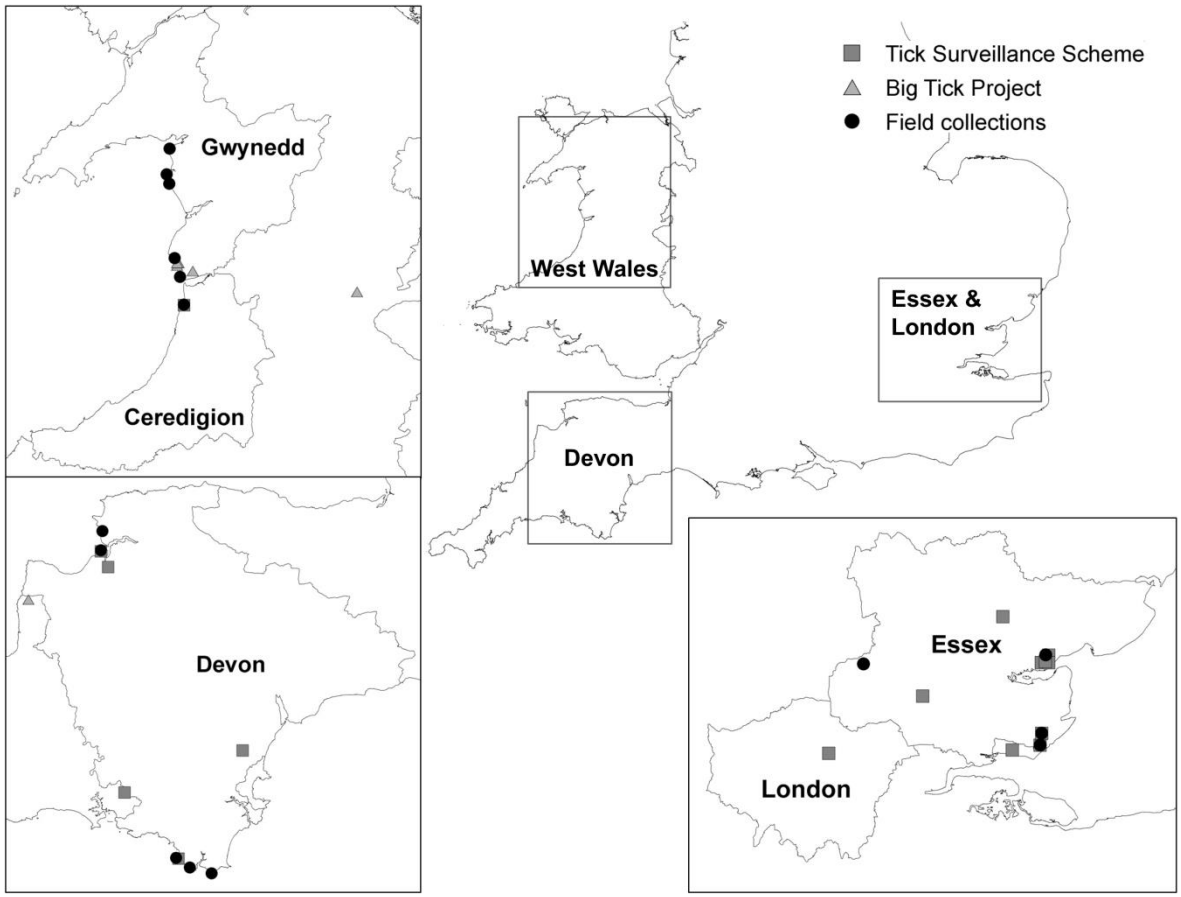
Tick Surveillance Scheme
Big Tick Project
Field collections
Gwynedd
Ceredigion
West Wales
Devon
Essex &
London
Devon
Essex
London

Fig 4